Equatorward transport of lower stratospheric air during CRYSTAL FACE: Analysis and implications

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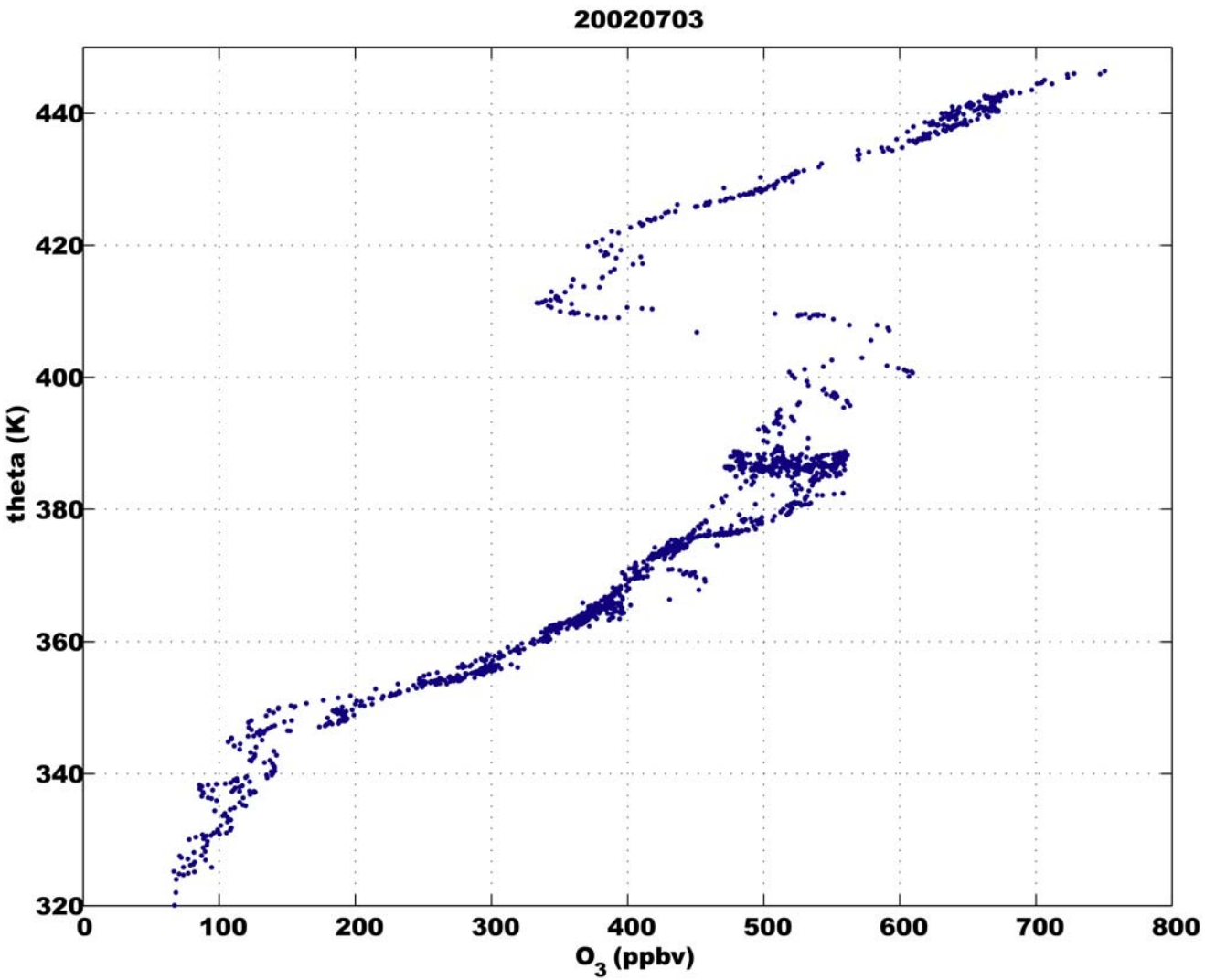
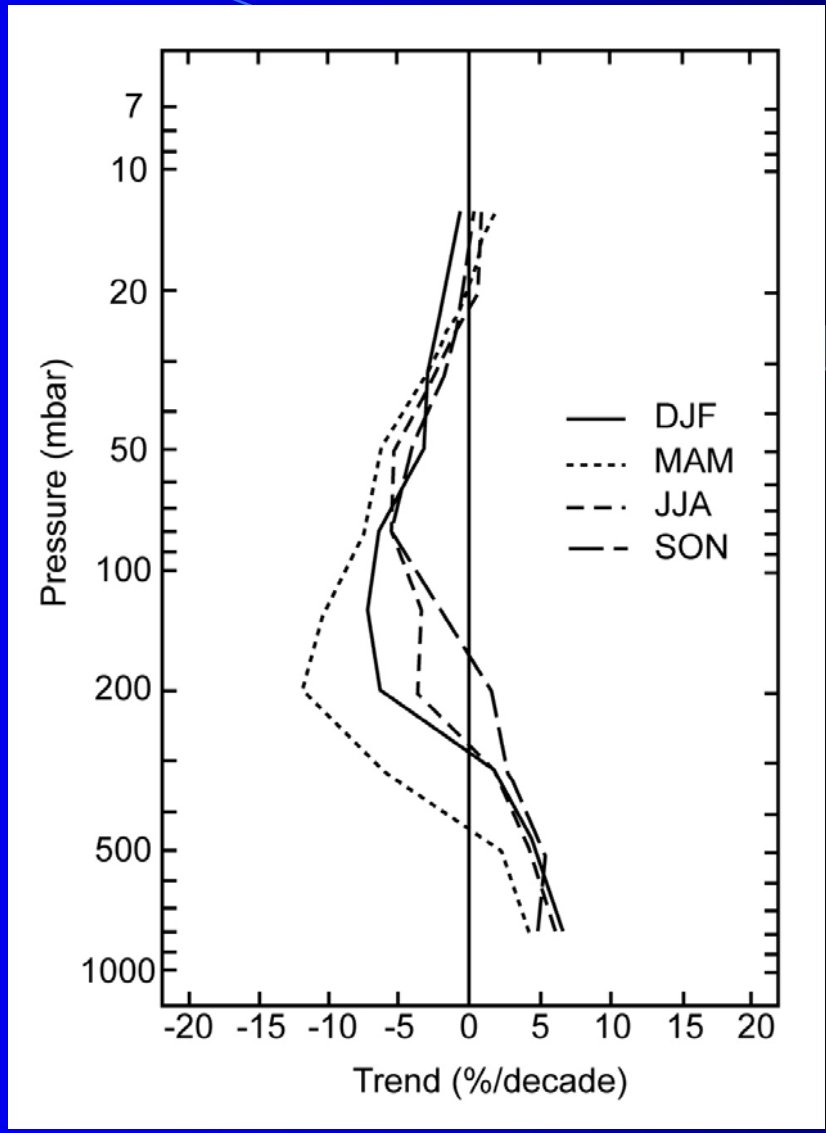
Introduction

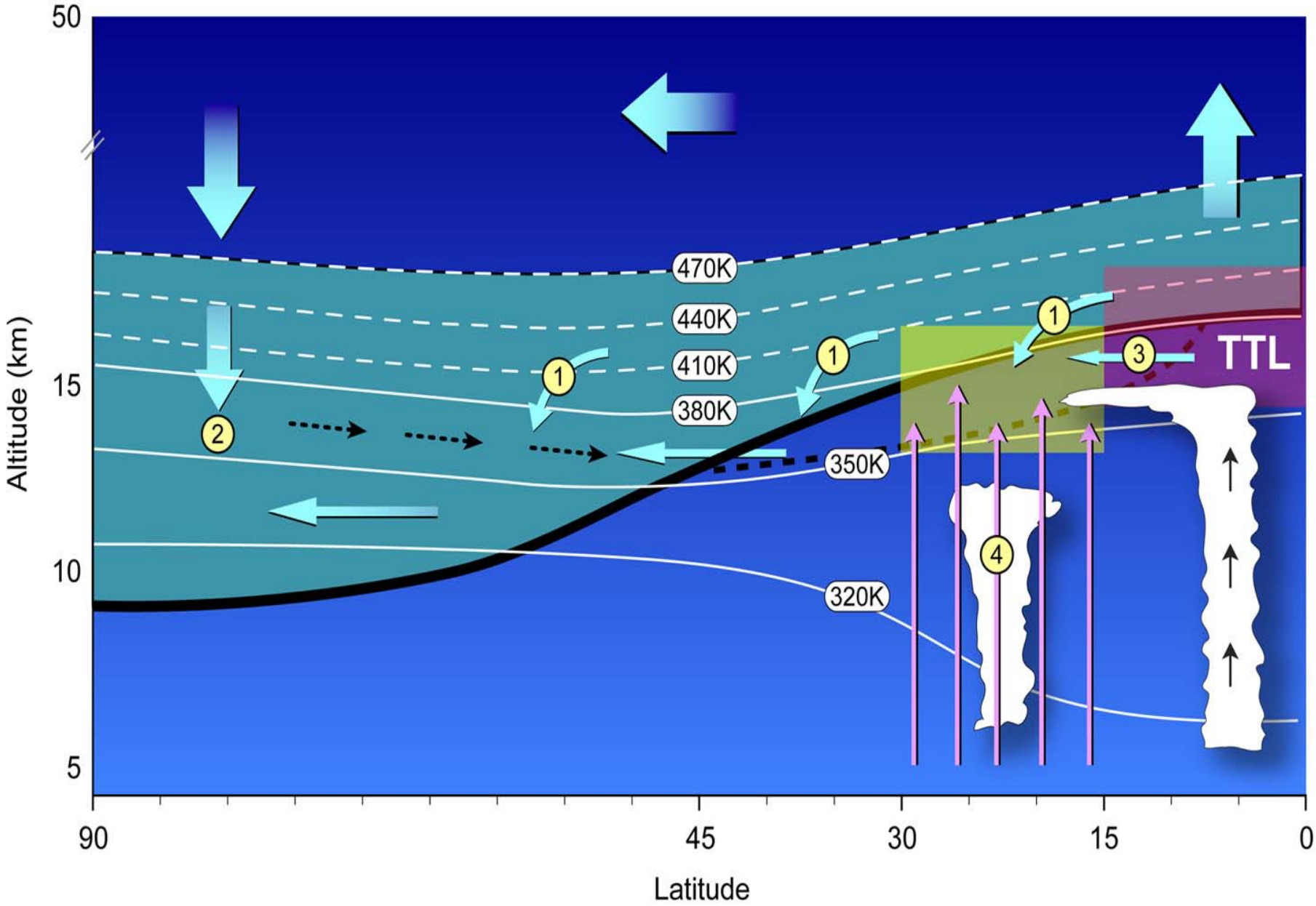
The lowermost stratosphere, the region in the extra-tropics bounded from above by the isentrope corresponding to the tropical tropopause, typically 380-390 K, and from below by the local tropopause, is a region that has been the focus of intense scrutiny in recent years.

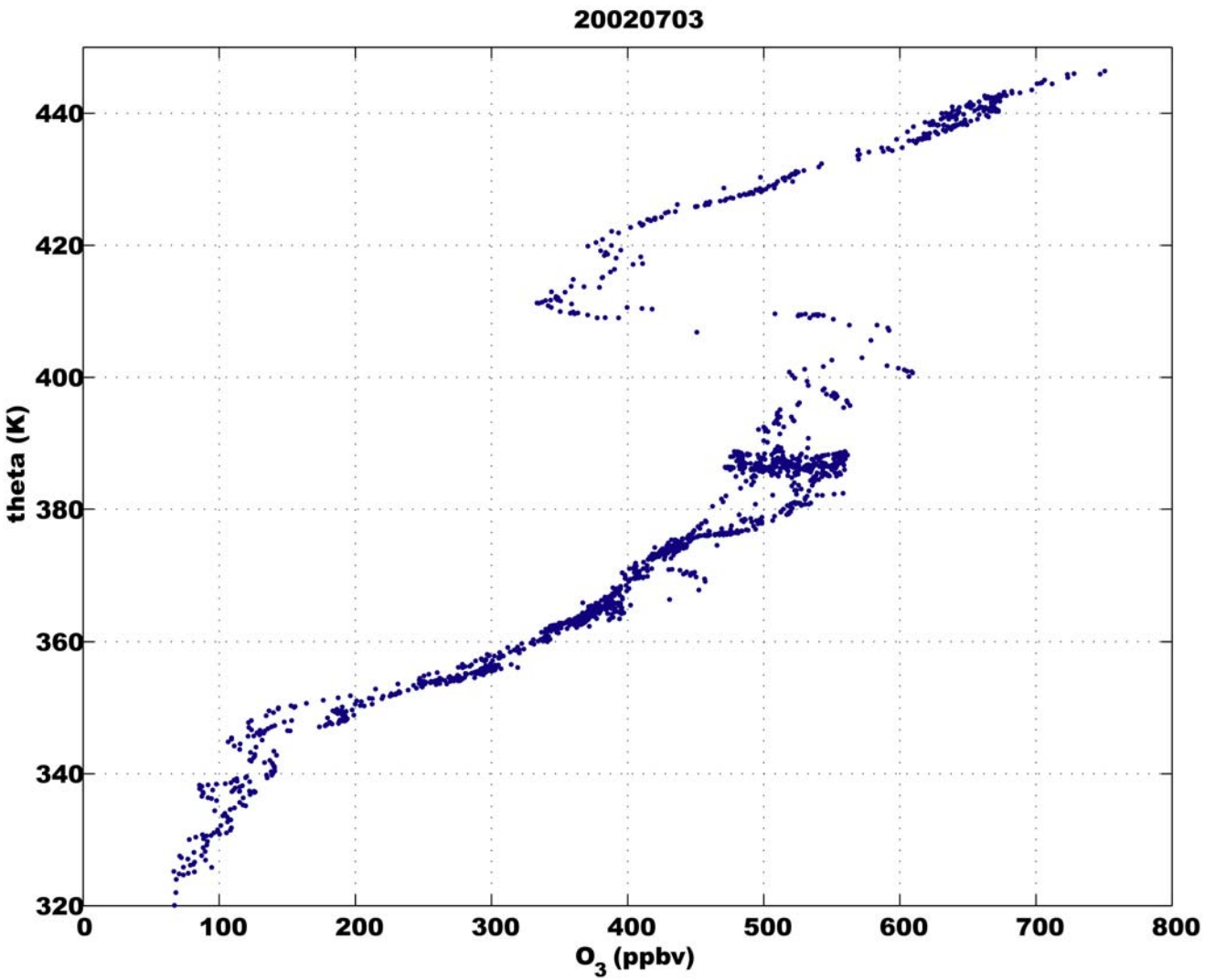

20020703
theta (K)
440
420
400
380
360
340
320
0
100
200
300
400
500
600
700
800
O3 (ppbv)

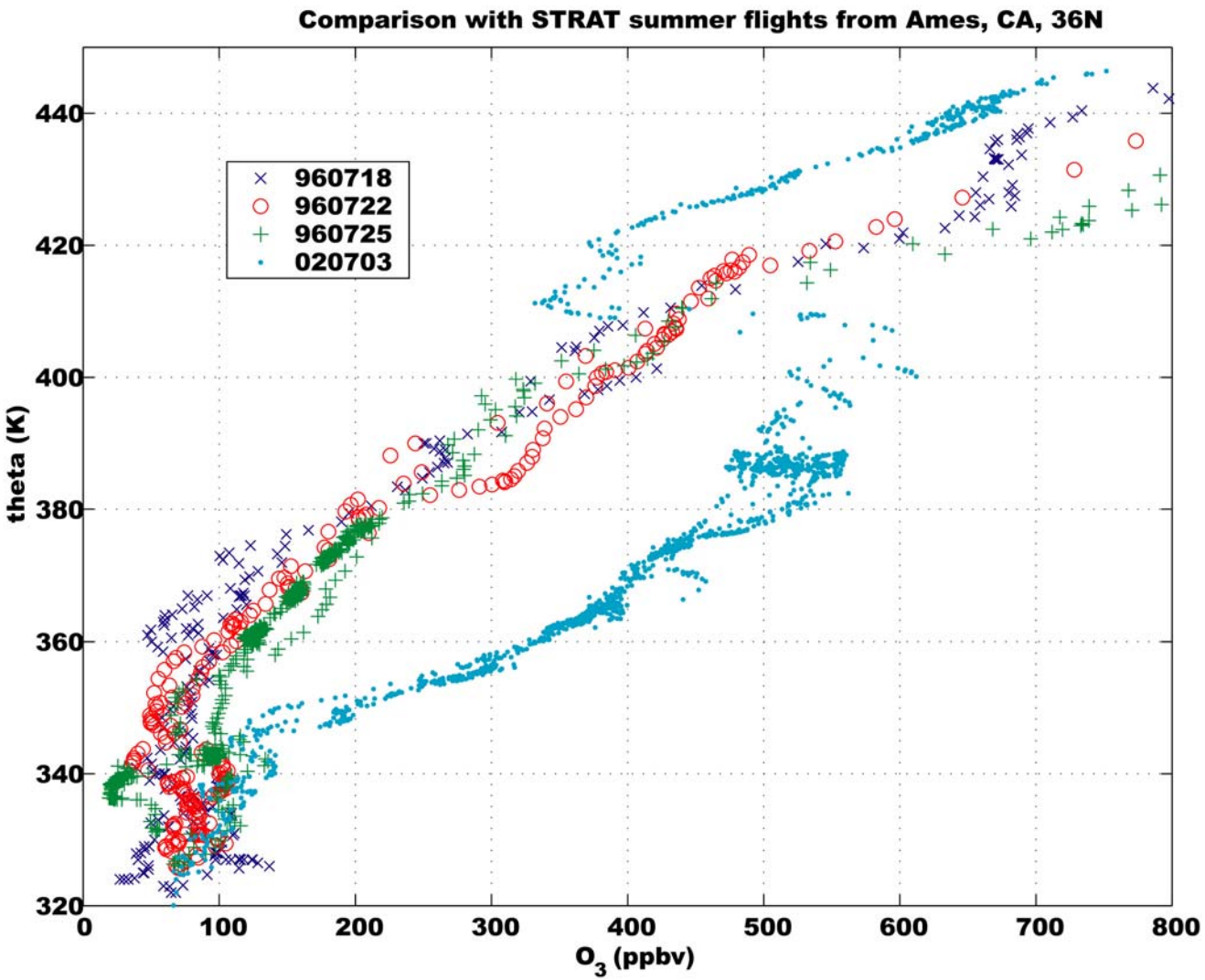
So, why do we care

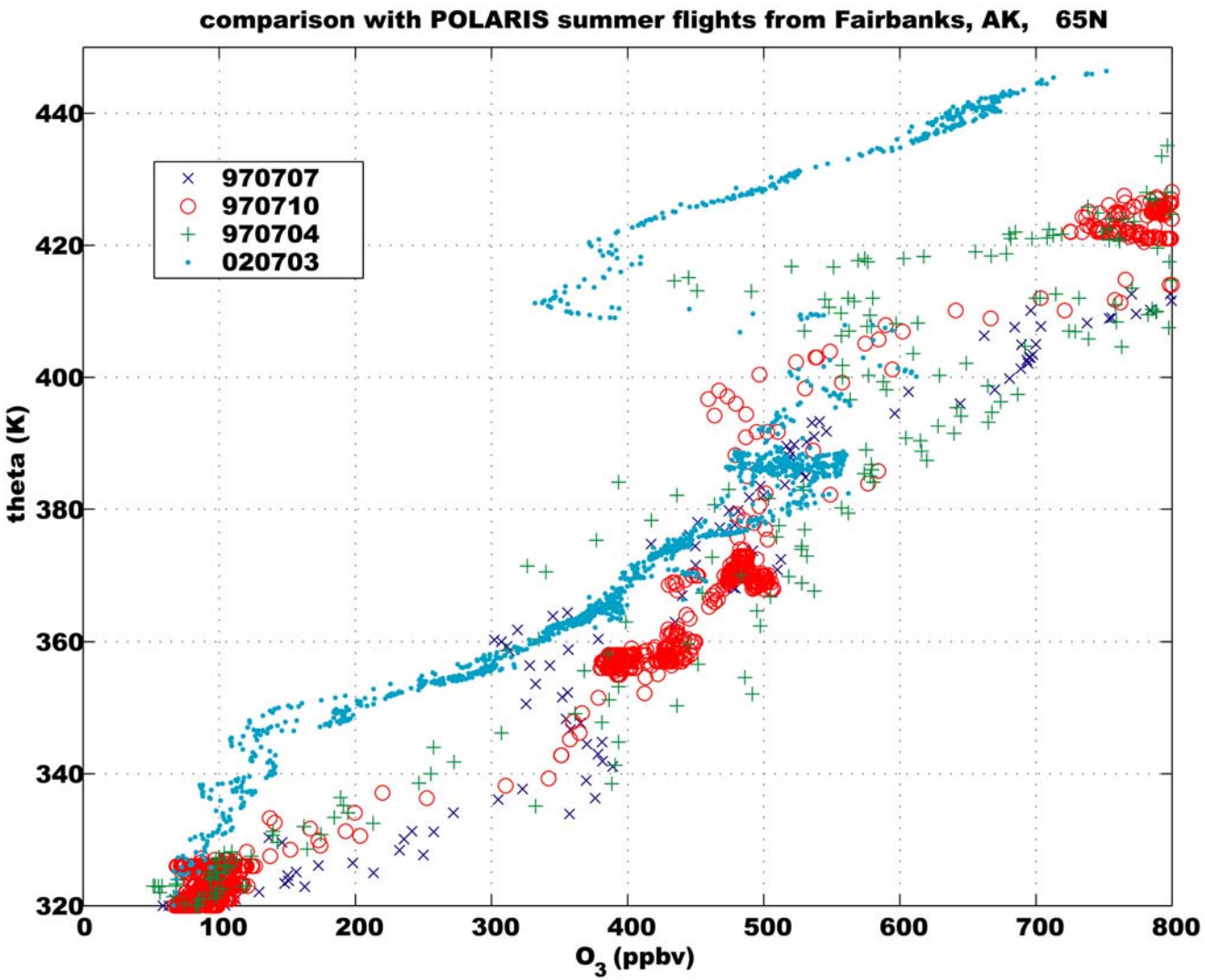
- **Ozone depletion/trends**
- Water vapor/heterogeneous chemistry/radiative effects
- **Transport of aircraft emissions**
- **Test transport in two- and three-D models**
- Cirrus cloud climatology/lifetime
- Gateway to the troposphere and ttl

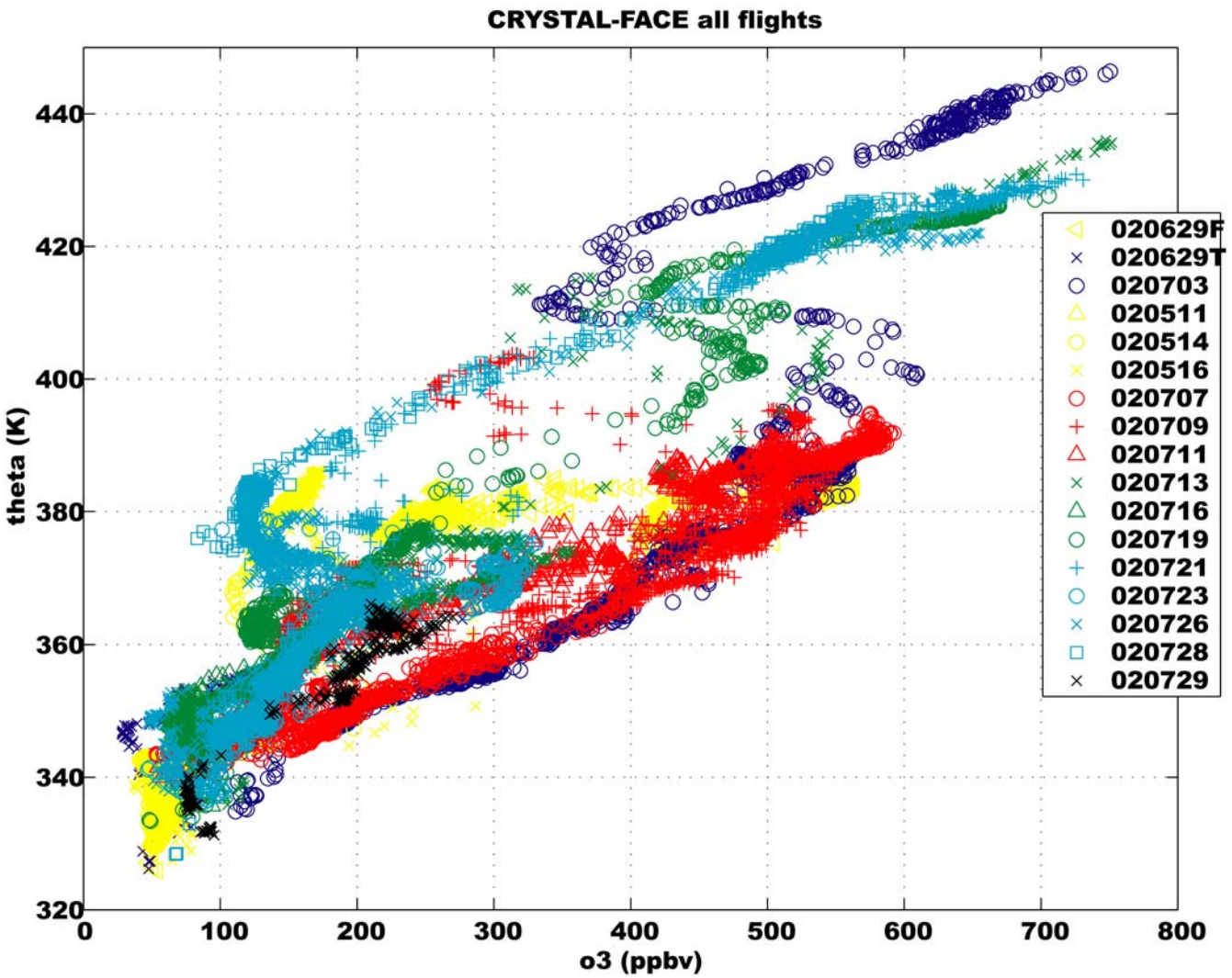

Pressure (mbar)
7
10
20
50
100
200
500
1000
-20
-15
-10
-5
0
5
10
15
20
Trend (%/decade)
DJF
MAM
JJA
SON

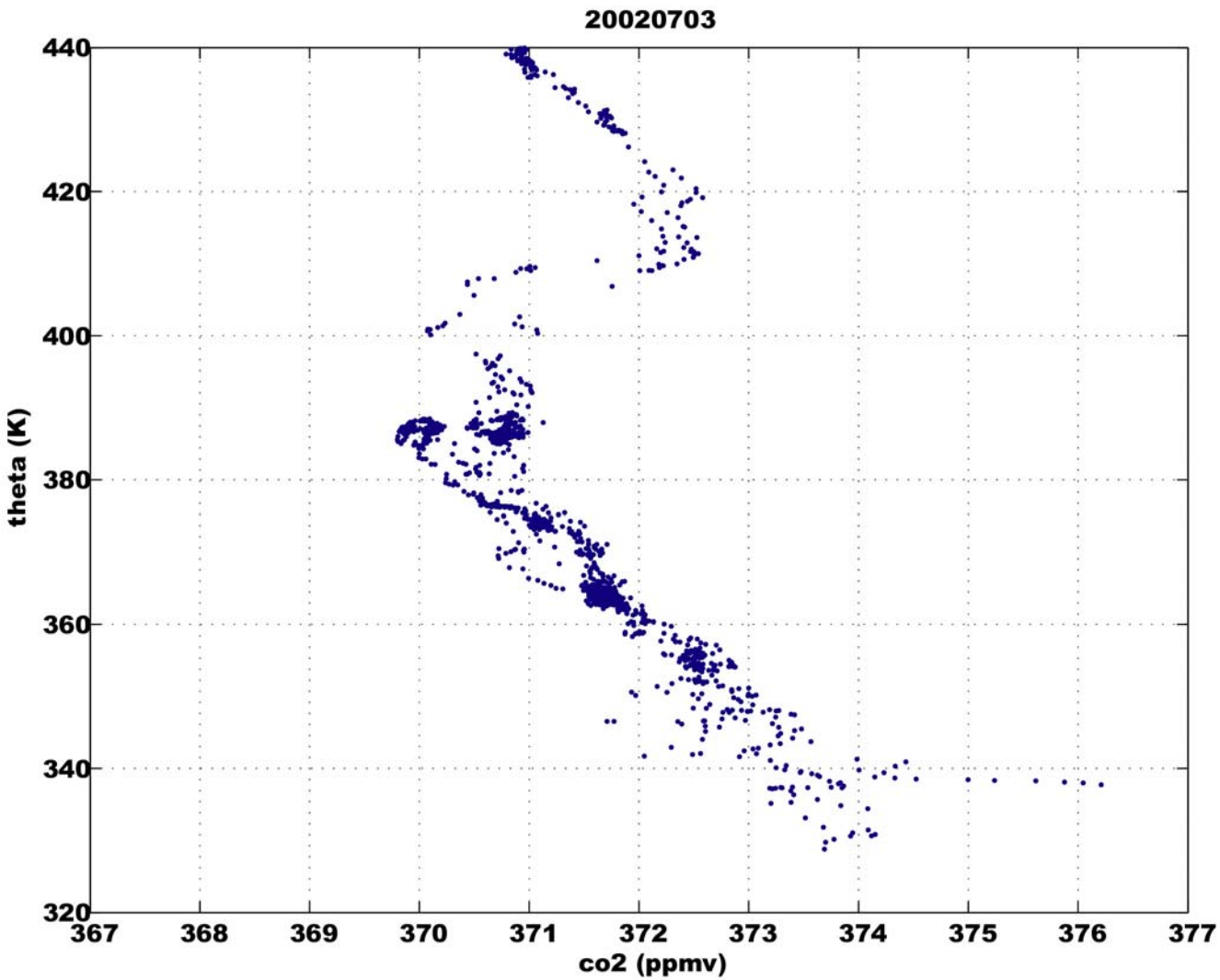

50
15
10
5
Altitude (km)
90
45
30
15
0
Latitude
470K
440K
410K
380K
350K
320K
1
1
1
2
3
4
TTL

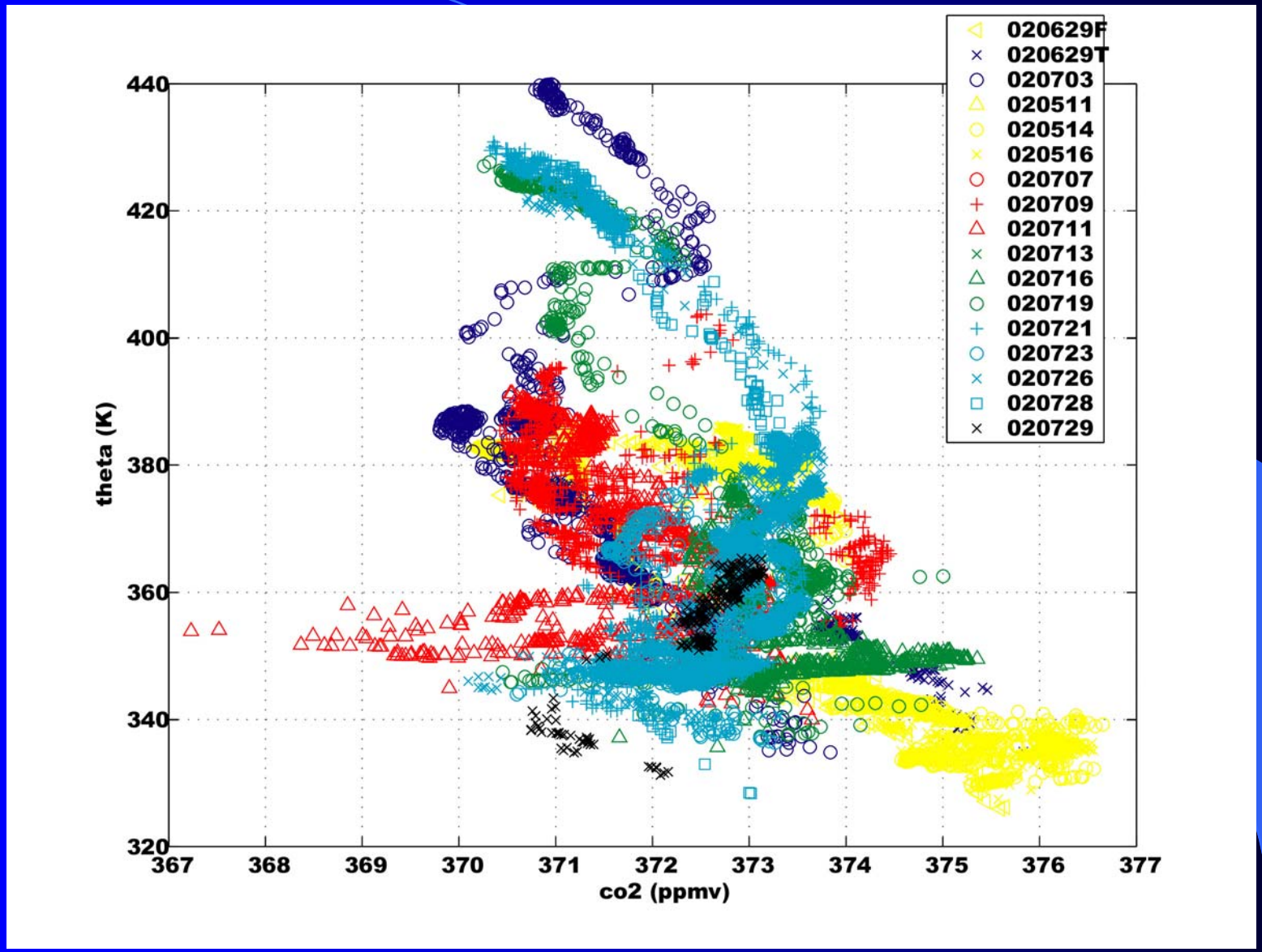

20020703
theta (K)
440
420
400
380
360
340
320
0
100
200
300
400
500
600
700
800
O3 (ppbv)

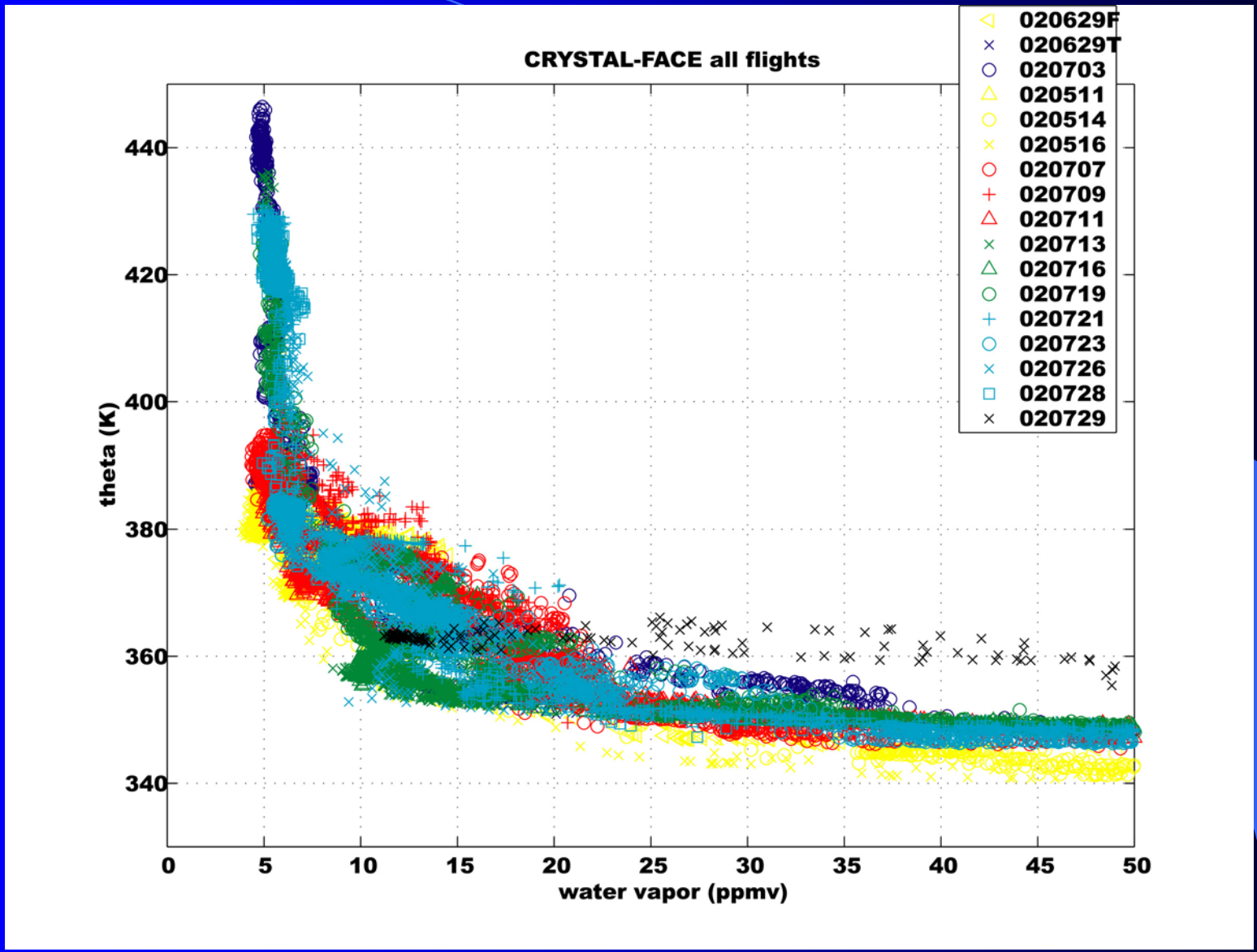

Comparison with STRAT summer flights from Ames, CA, 36N
960718
960722
960725
020703
theta (K)
O3 (ppbv)
320
340
360
380
400
420
440
0
100
200
300
400
500
600
700
800

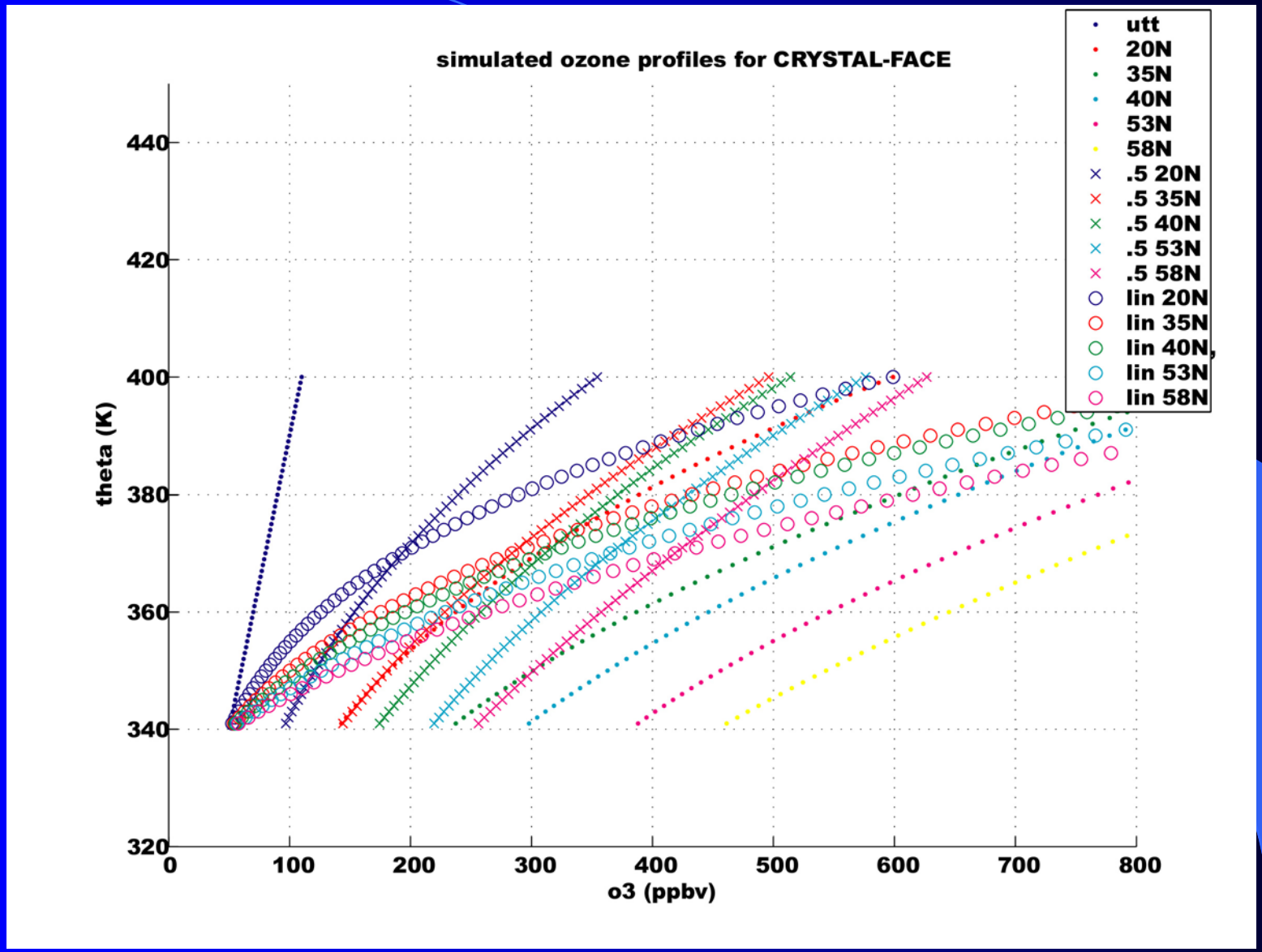

comparison with POLARIS summer flights from Fairbanks, AK, 65N
970707
970710
970704
020703
theta (K)
440
420
400
380
360
340
320
0
100
200
300
400
500
600
700
800
O3 (ppbv)

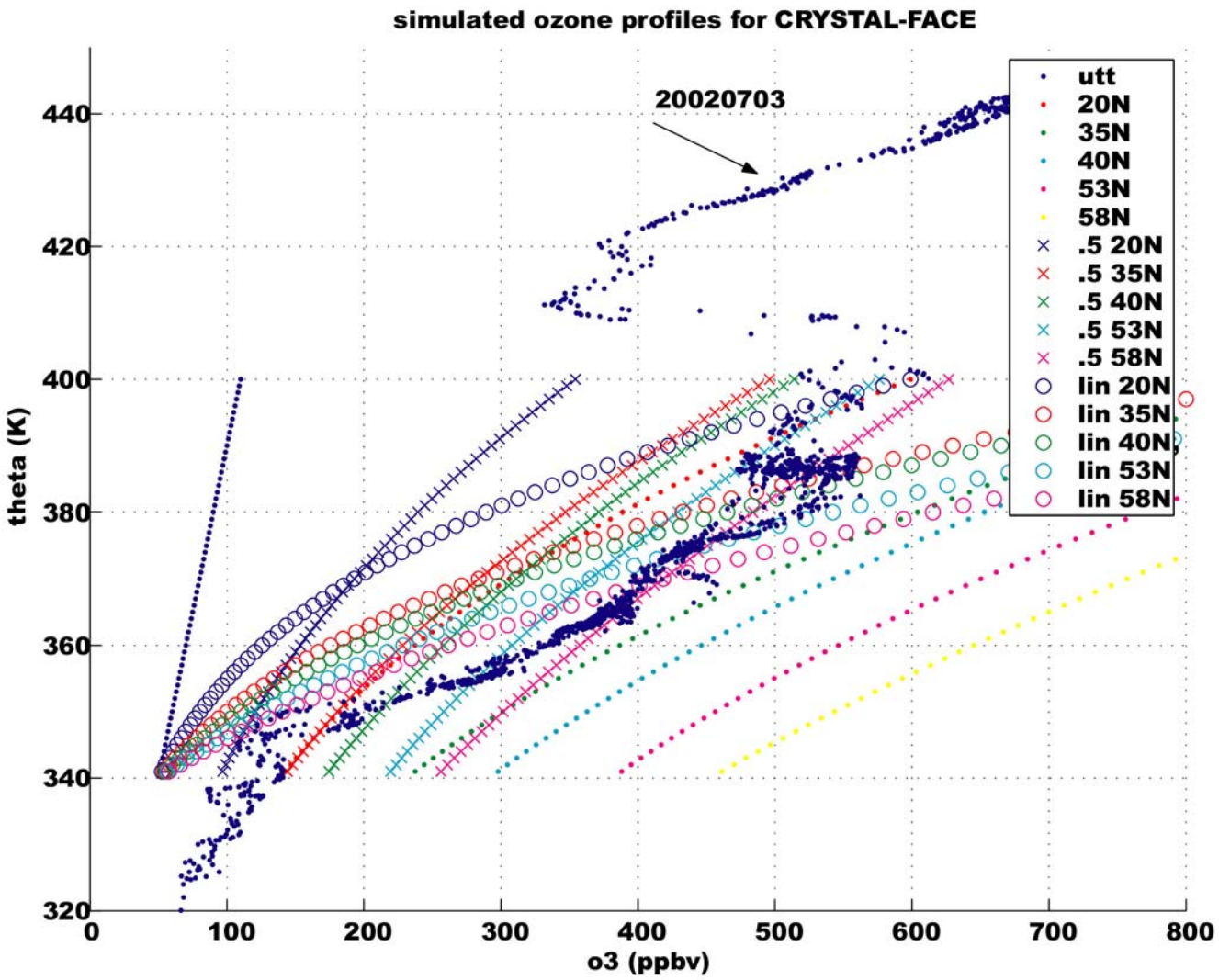

CRYSTAL-FACE all flights
theta (K)
o3 (ppbv)
320
340
360
380
400
420
440
0
100
200
300
400
500
600
700
800
020629F
020629T
020703
020511
020514
020516
020707
020709
020711
020713
020716
020719
020721
020723
020726
020728
020729

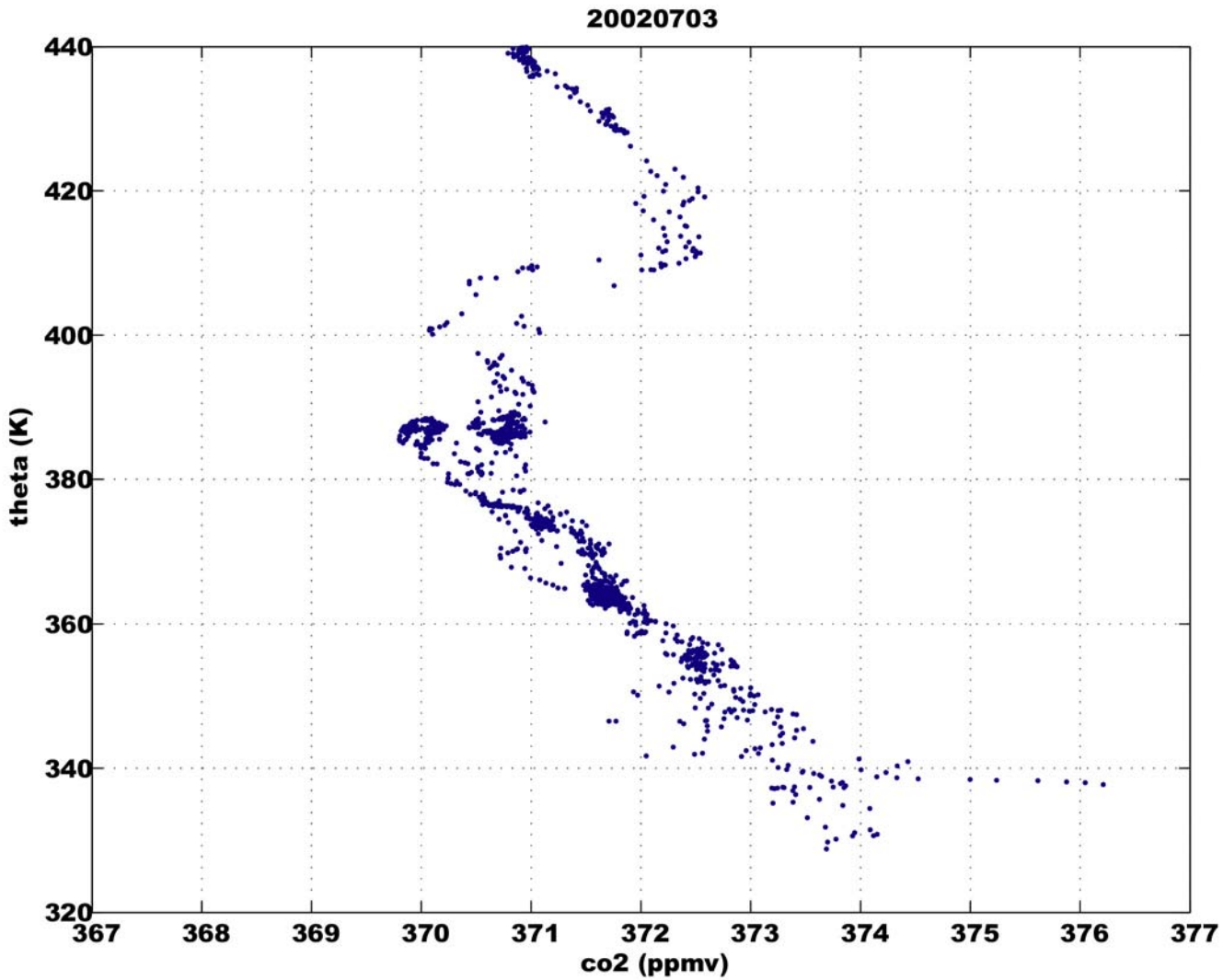

20020703
440
420
400
380
360
340
320
theta (K)
367
368
369
370
371
372
373
374
375
376
377
co2 (ppmv)

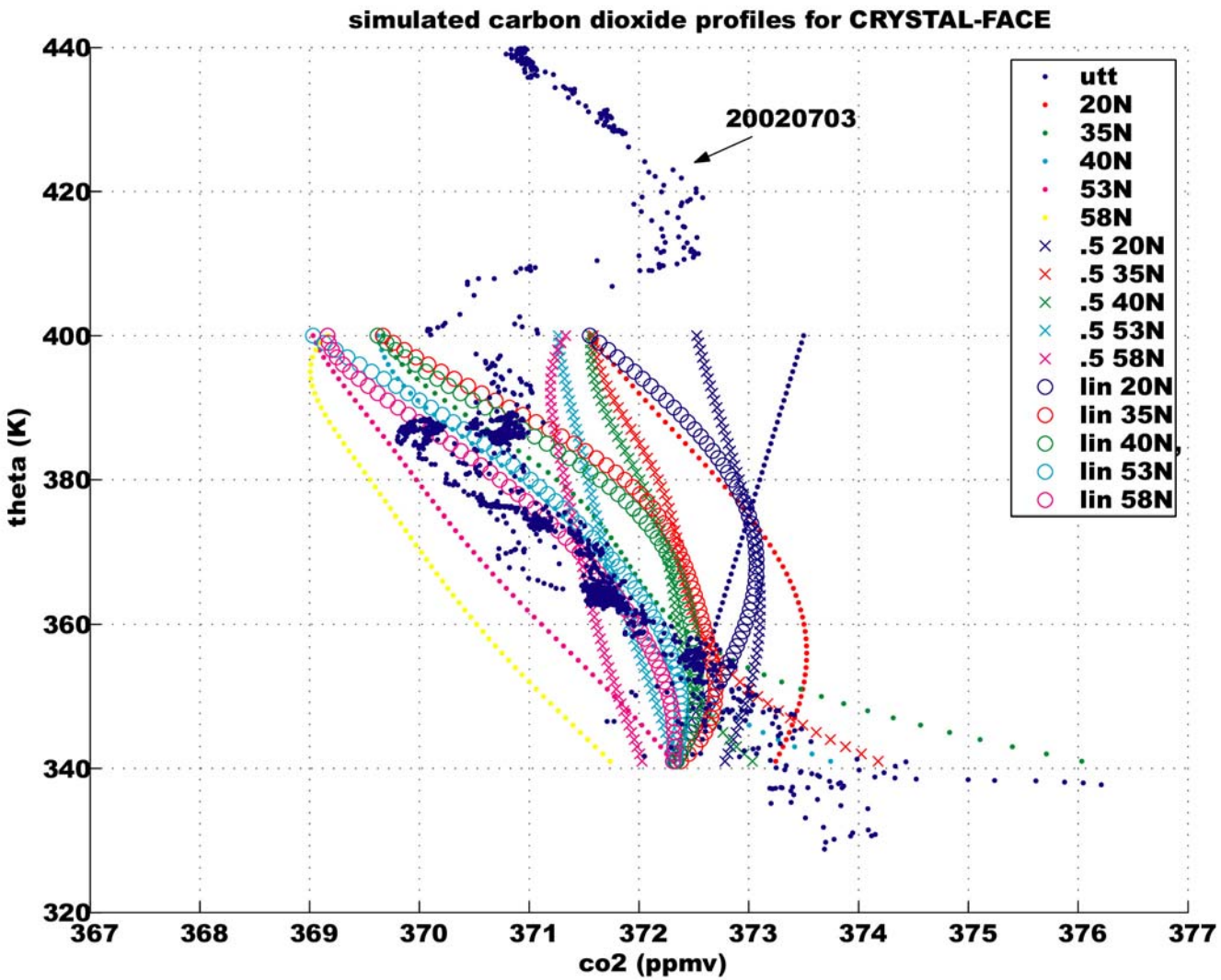

020629F
020629T
020703
020511
020514
020516
020707
020709
020711
020713
020716
020719
020721
020723
020726
020728
020729
theta (K)
co2 (ppmv)
440
420
400
380
360
340
320
367
368
369
370
371
372
373
374
375
376
377

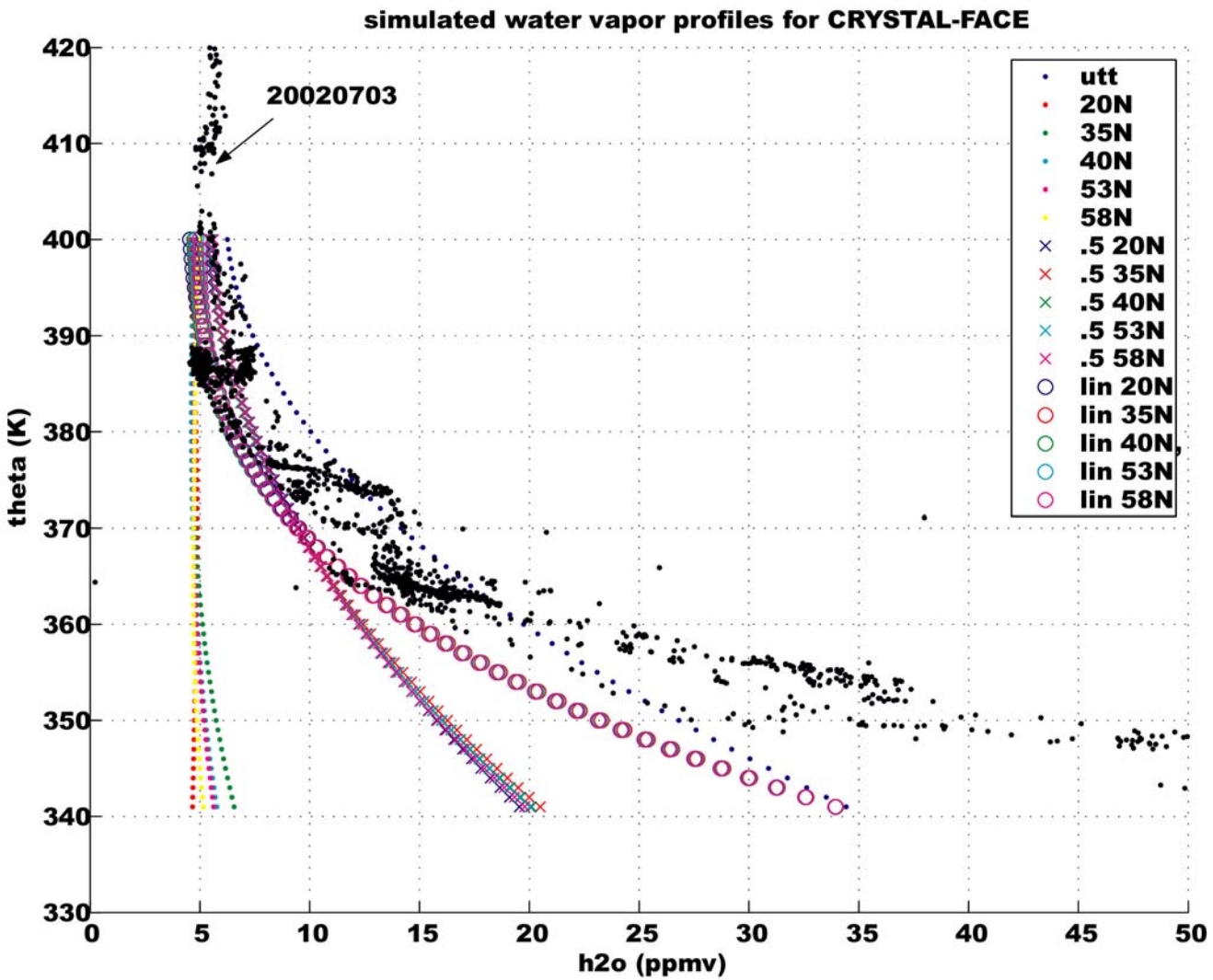

CRYSTAL-FACE all flights
020629F
020629T
020703
020511
020514
020516
020707
020709
020711
020713
020716
020719
020721
020723
020726
020728
020729
theta (K)
440
420
400
380
360
340
0
5
10
15
20
25
30
35
40
45
50
water vapor (ppmv)


simulated ozone profiles for CRYSTAL-FACE
utt
20N
35N
40N
53N
58N
.5 20N
.5 35N
.5 40N
.5 53N
.5 58N
lin 20N
lin 35N
lin 40N,
lin 53N
lin 58N
theta (K)
o3 (ppbv)
320
340
360
380
400
420
440
0
100
200
300
400
500
600
700
800


simulated ozone profiles for CRYSTAL-FACE
20020703
utt
20N
35N
40N
53N
58N
.5 20N
.5 35N
.5 40N
.5 53N
.5 58N
lin 20N
lin 35N
lin 40N
lin 53N
lin 58N
theta (K)
o3 (ppbv)
320
340
360
380
400
420
440
0
100
200
300
400
500
600
700
800

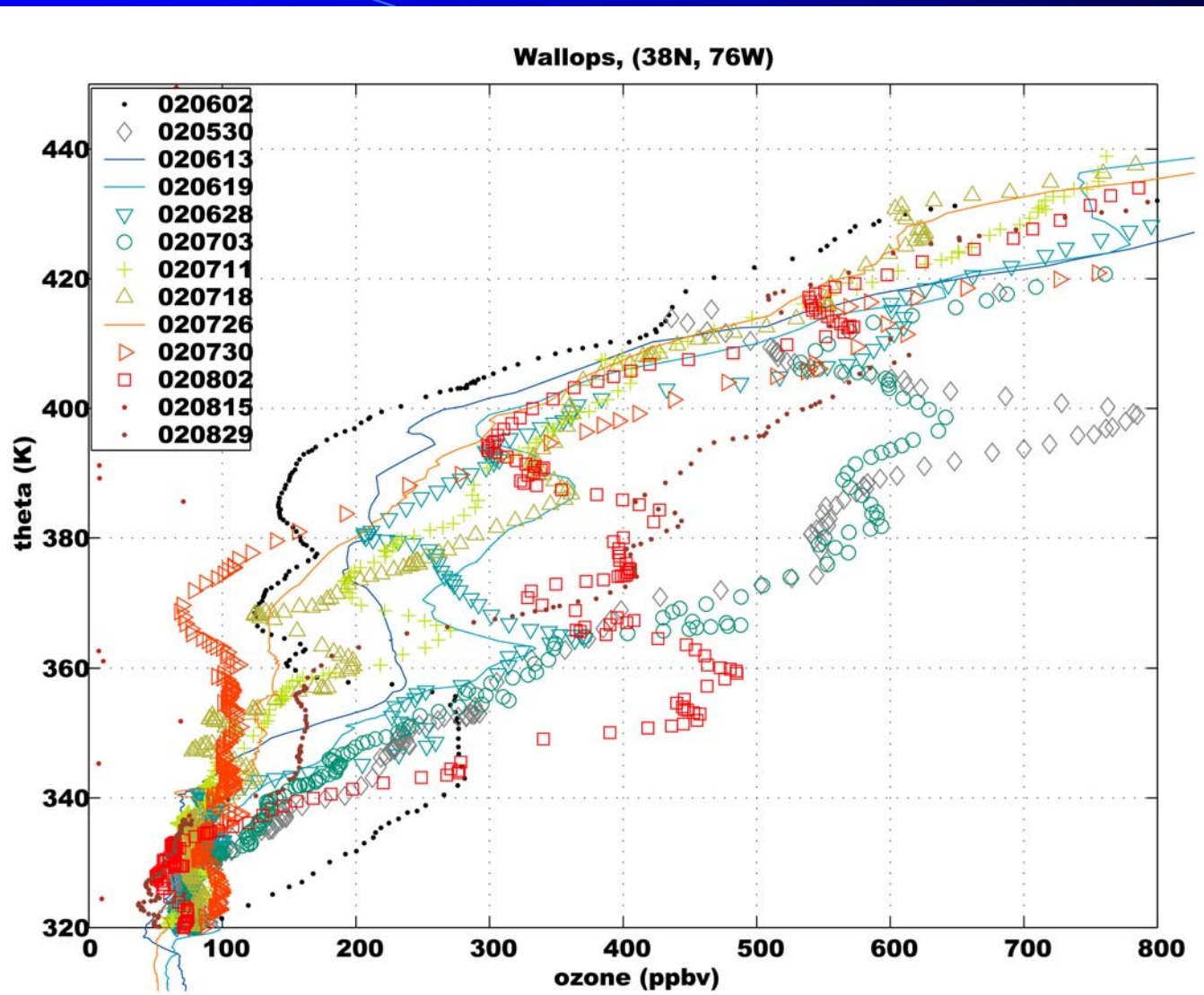

20020703
theta (K)
440
420
400
380
360
340
320
367
368
369
370
371
372
373
374
375
376
377
co2 (ppmv)

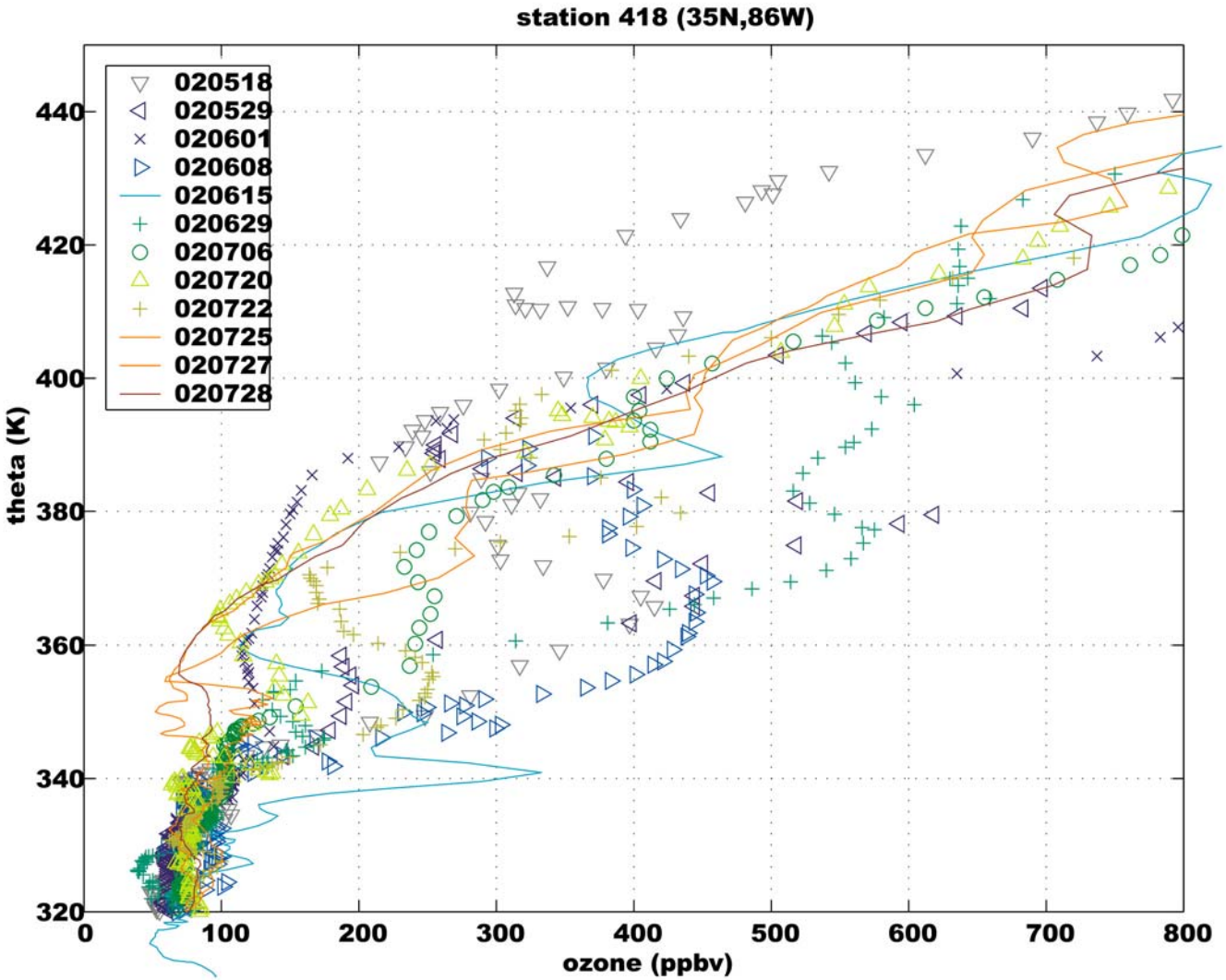

simulated carbon dioxide profiles for CRYSTAL-FACE
20020703
utt
20N
35N
40N
53N
58N
.5 20N
.5 35N
.5 40N
.5 53N
.5 58N
lin 20N
lin 35N
lin 40N
lin 53N
lin 58N
theta (K)
co2 (ppmv)
440
420
400
380
360
340
320
367
368
369
370
371
372
373
374
375
376
377

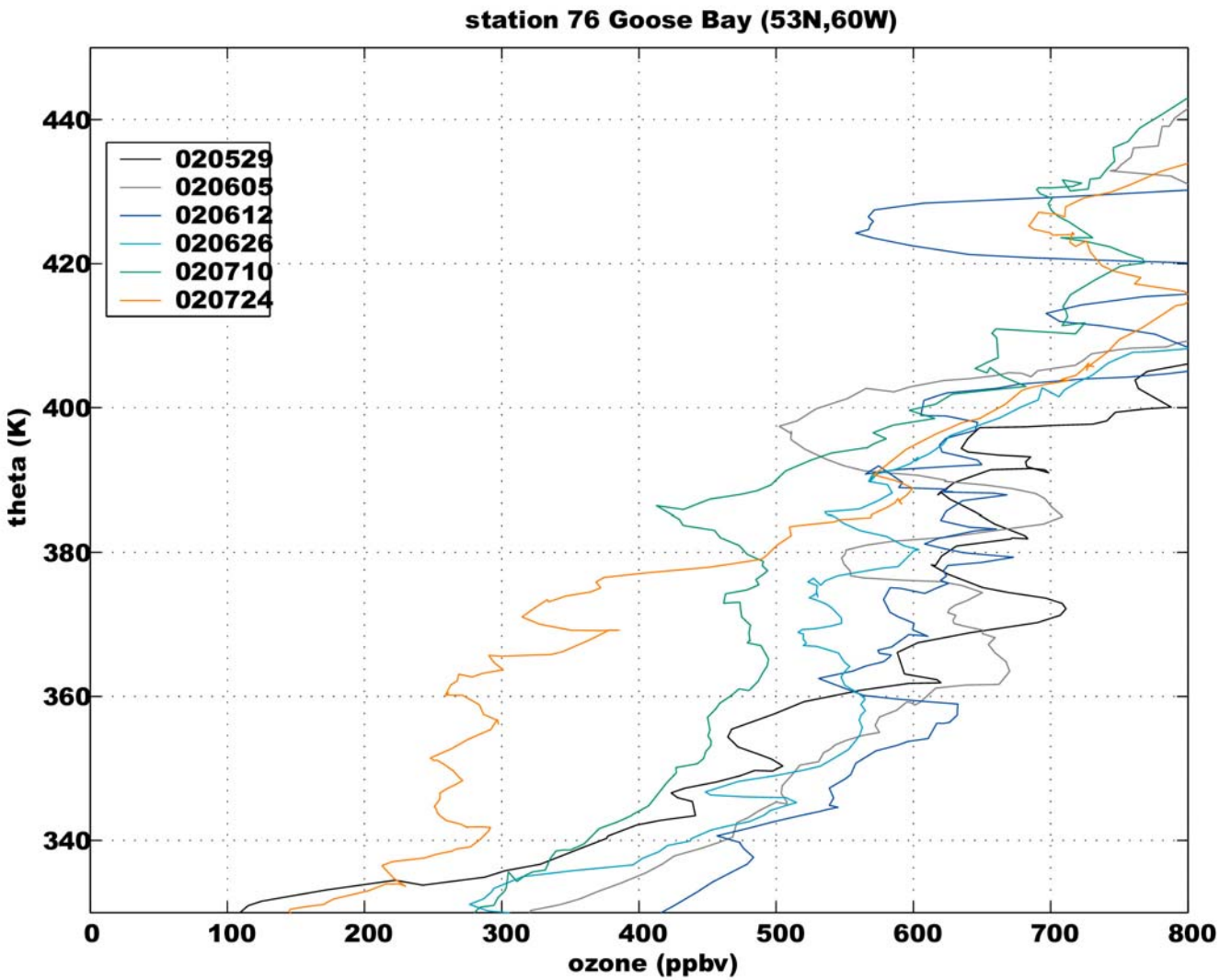

simulated water vapor profiles for CRYSTAL-FACE
20020703
utt
20N
35N
40N
53N
58N
.5 20N
.5 35N
.5 40N
.5 53N
.5 58N
lin 20N
lin 35N
lin 40N
lin 53N
lin 58N
theta (K)
h2o (ppmv)
420
410
400
390
380
370
360
350
340
330
0
5
10
15
20
25
30
35
40
45
50

Use of middleworld data from ozonesondes

- Logan has proposed using ozonesonde data to help constrain transport models because of availability of year round data and the number of stations in the northern hemisphere.
- Reid et al. analyzed ozonesonde data to suggest that there is an increase in the transport of ozone poor air from the UTT, producing ozone minima at northern midlatitudes.
- Newchurch et al. analyzed recent ozonesonde data from four USA sites to develop an ozone climatology. They attributed enhanced ozone extending into the upper troposphere to localized tropopause folds. In these cases there was very little gradient in ozone across the tropopause. There is no evidence in their analysis of data from the Huntsville and Wallops Island sites of unusually high ozone in the middle world during summer.

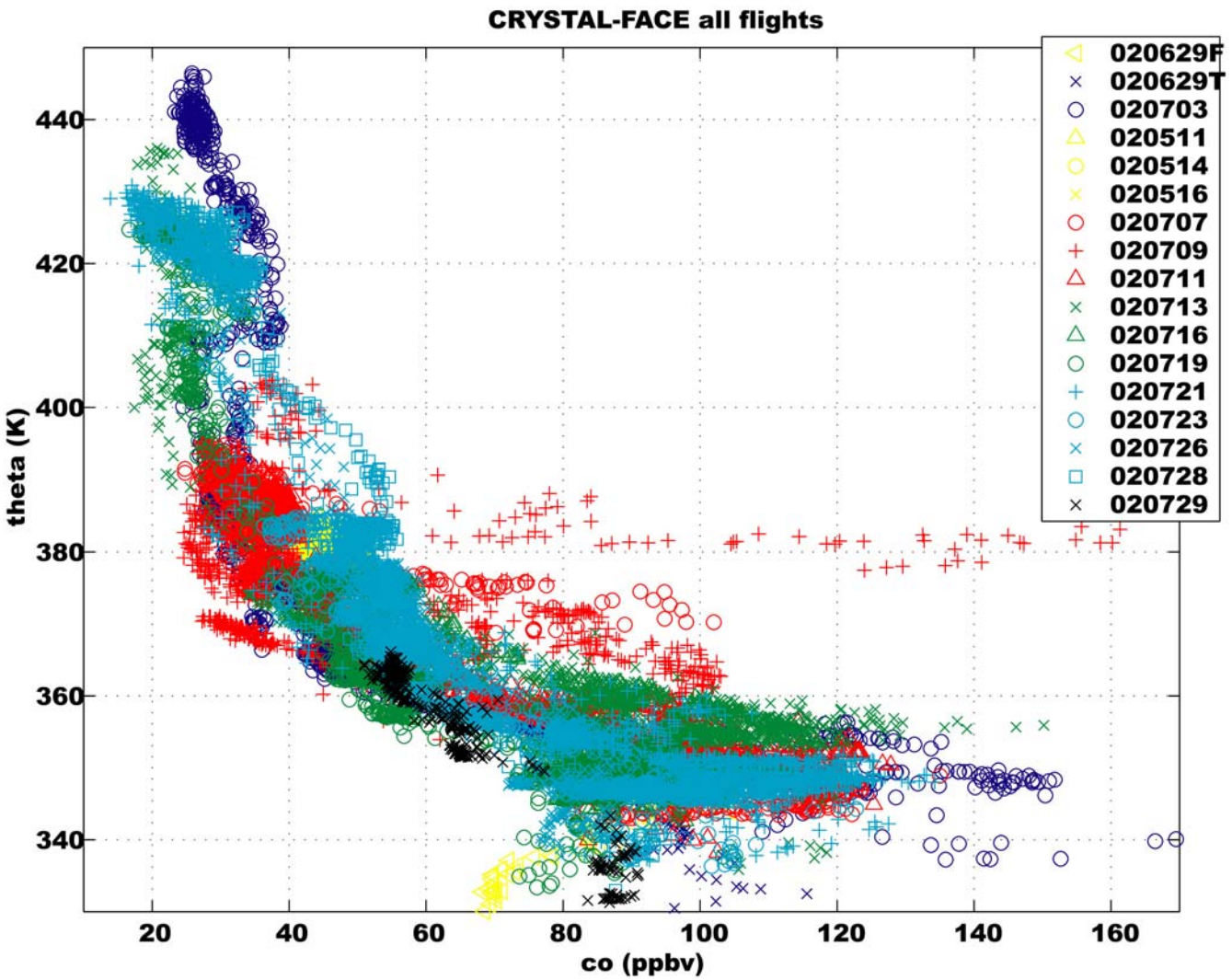

Wallops, (38N, 76W)
020602
020530
020613
020619
020628
020703
020711
020718
020726
020730
020802
020815
020829
theta (K)
440
420
400
380
360
340
320
0
100
200
300
400
500
600
700
800
ozone (ppbv)

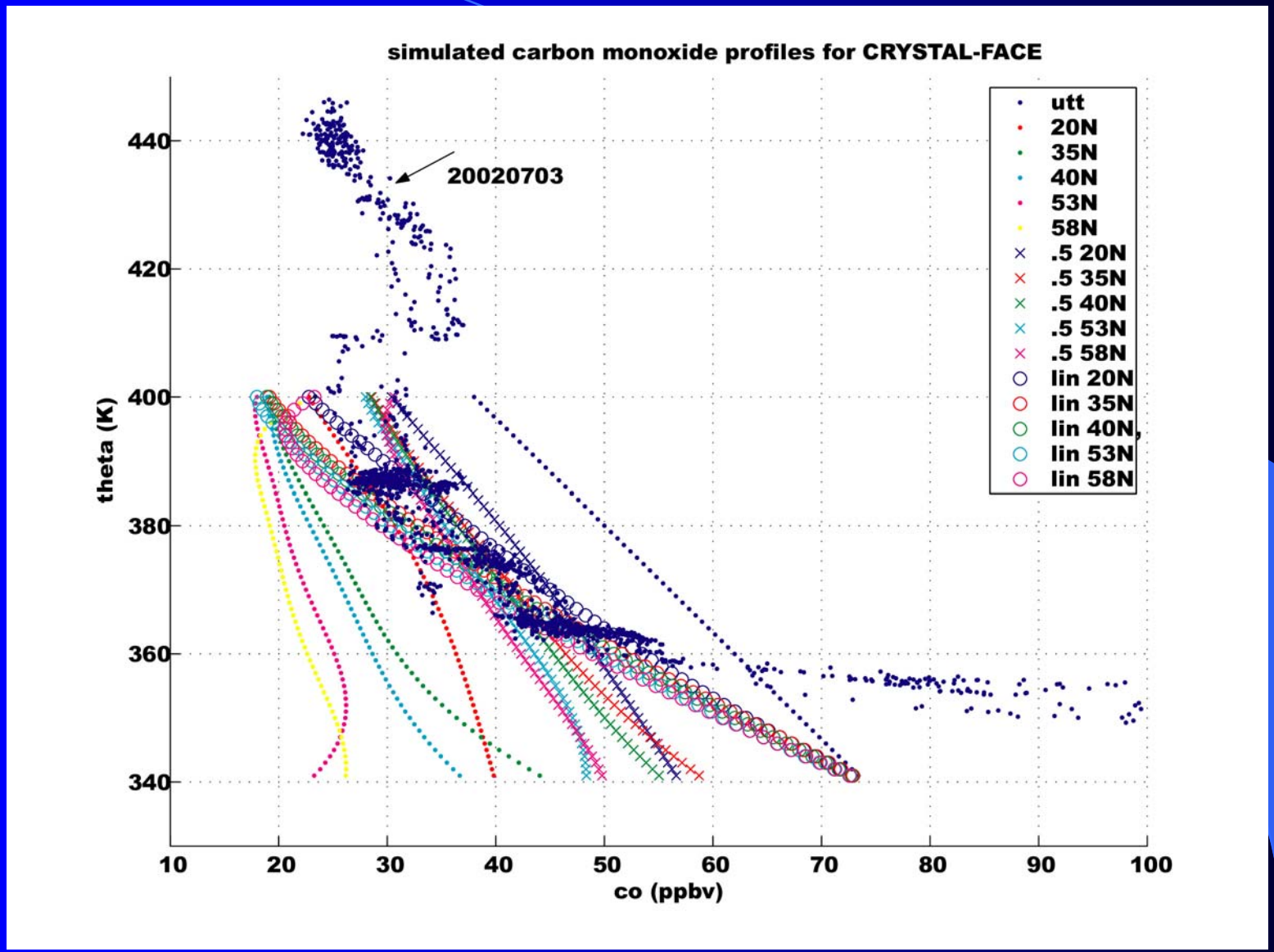

station 418 (35N,86W)
020518
020529
020601
020608
020615
020629
020706
020720
020722
020725
020727
020728
theta (K)
ozone (ppbv)
320
340
360
380
400
420
440
0
100
200
300
400
500
600
700
800

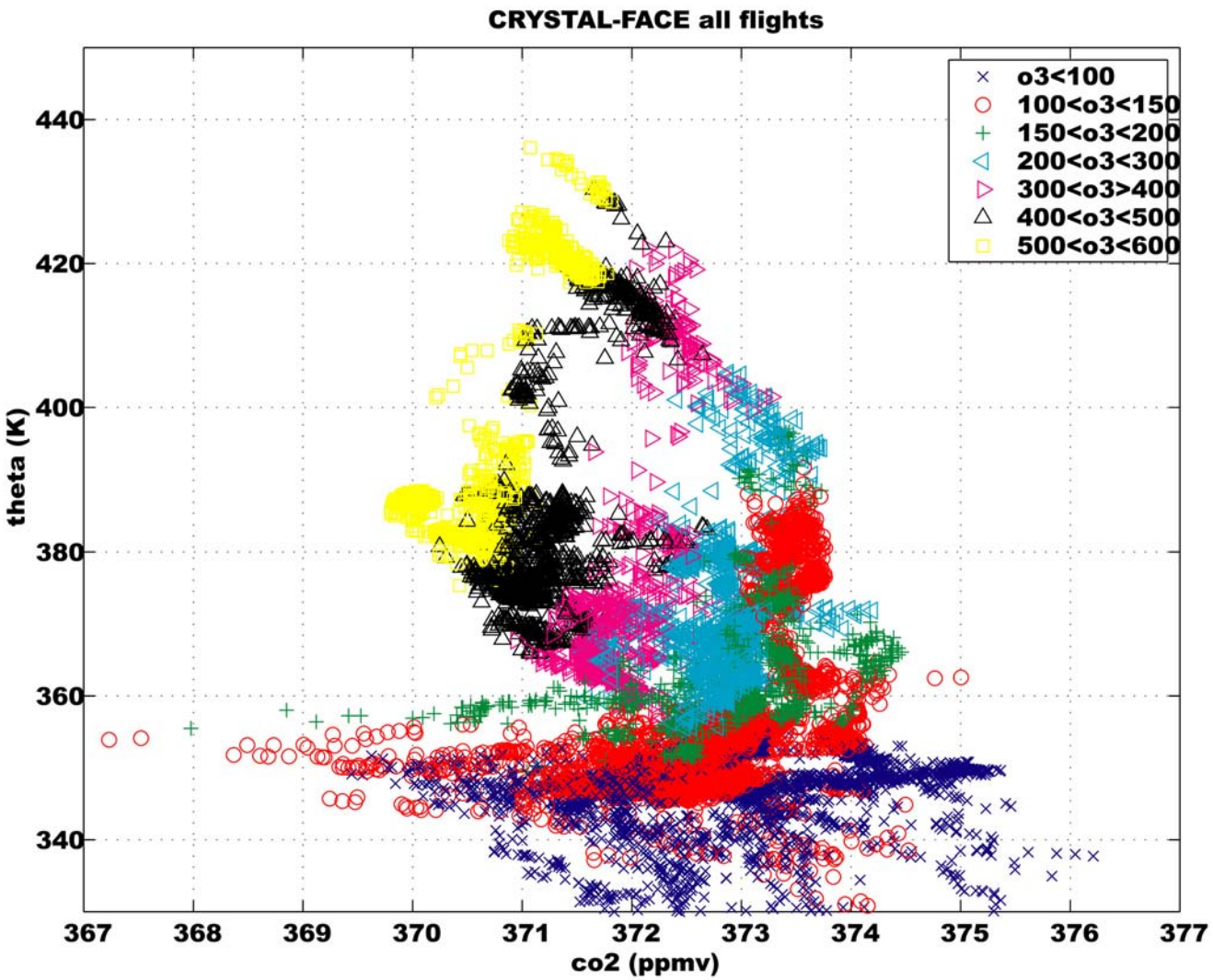

station 76 Goose Bay (53N,60W)
020529
020605
020612
020626
020710
020724
theta (K)
440
420
400
380
360
340
0
100
200
300
400
500
600
700
800
ozone (ppbv)

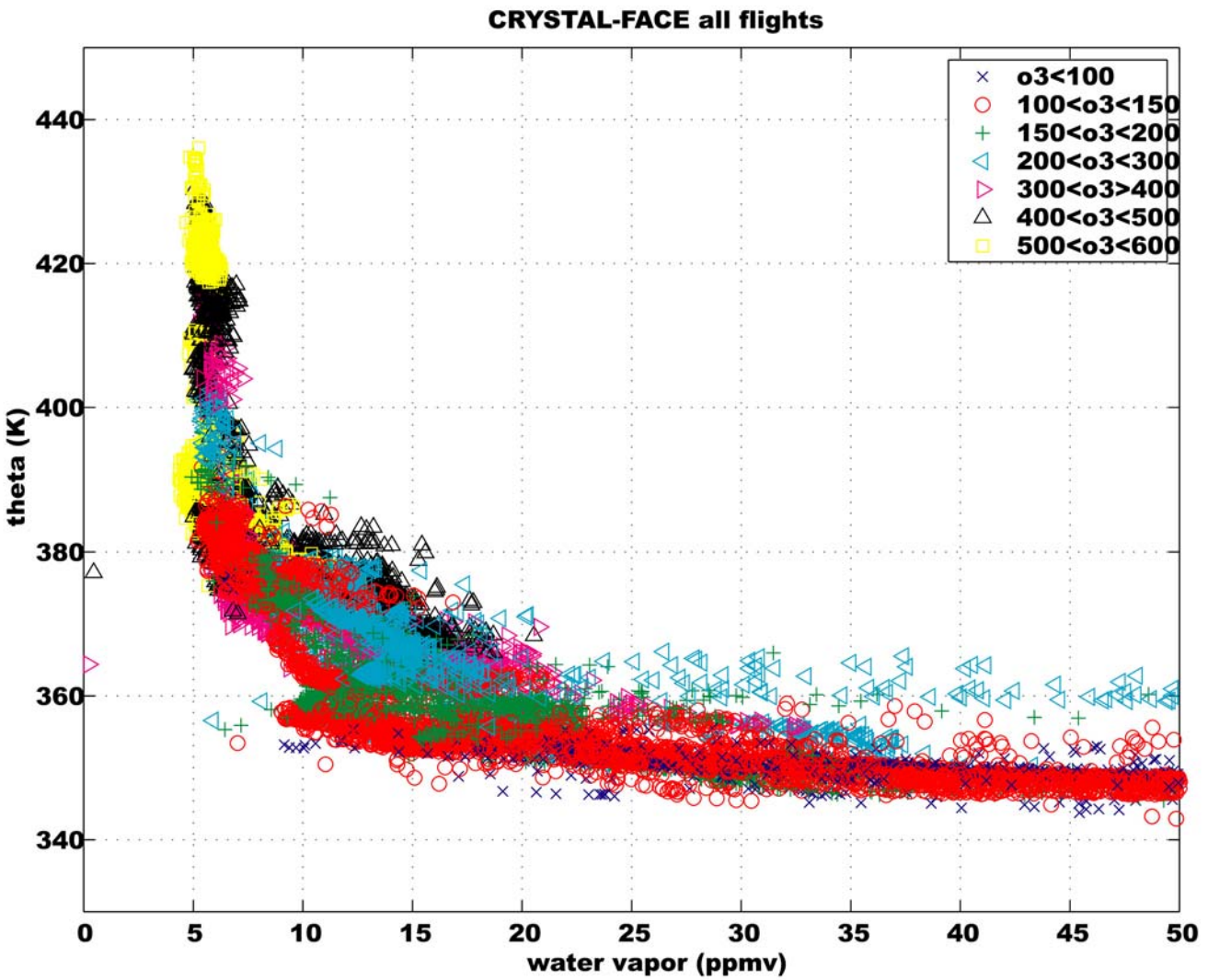
Conclusions

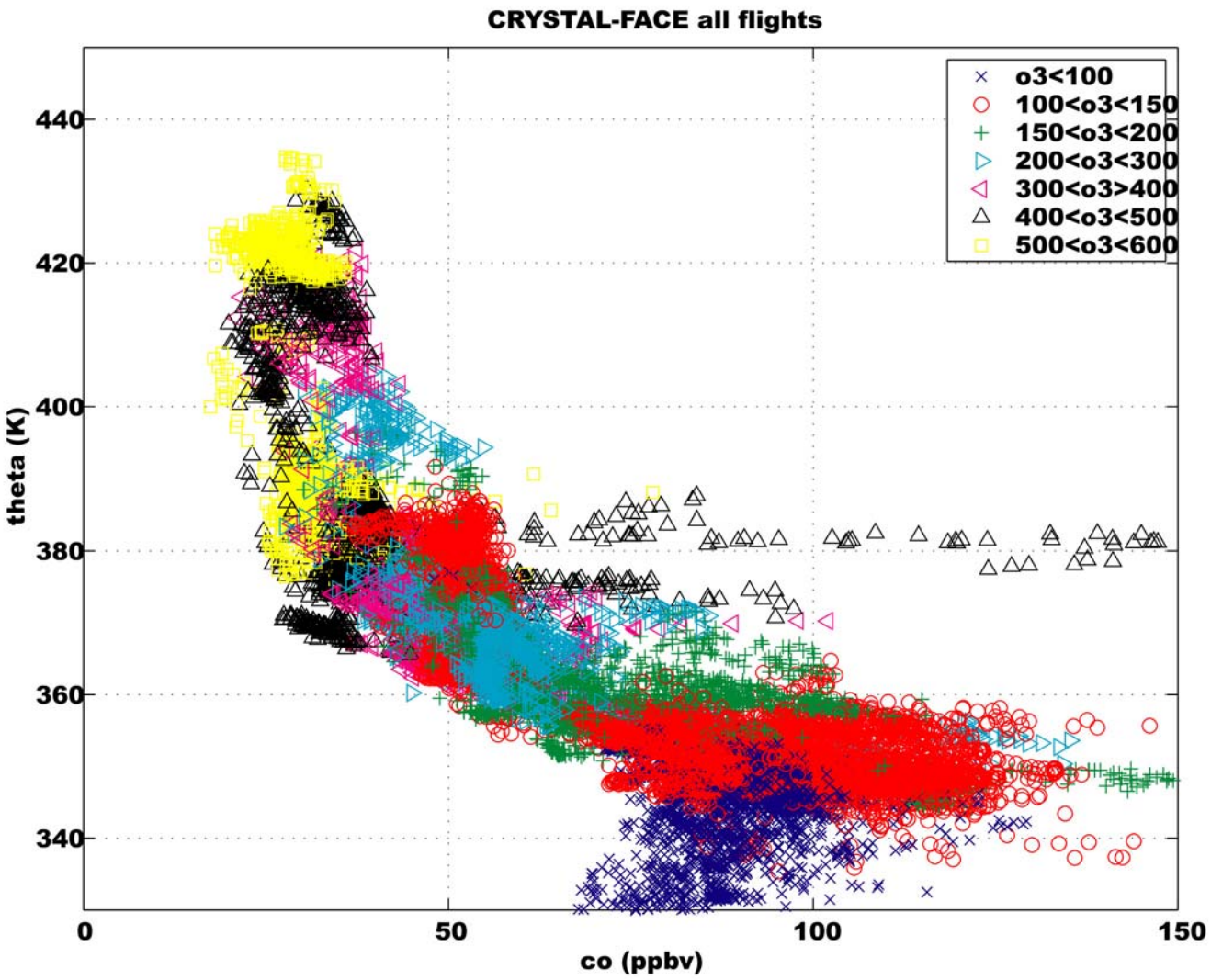
- During early to mid-July over Florida there were episodes during which much of the air in the lower stratosphere, from about 410 K to 350 K, has been isentropically transported from northern mid-latitudes where it has mixed with air isentropically transported from the upper tropical troposphere or TTL as well convectively transported from the local troposphere. This interpretation is consistent with high ozone values and constrained by H_2O values and CO_2 values consistent with the phases of its seasonal cycle.
- Evidence of this transport pathway is uniquely illustrated by tracer measurements during CRYSTAL FACE . While this pathway has been suggested as part of meridional motion associated with summer monsoons, it has not been identified by analysis of ozonesondes in the ozonesonde network, and is not apparent in other in situ data sets. This pathway, is seen here during the summer, when descent in the lower stratosphere is minimal.
- Detailed examination of ozonesonde data might provide additional evidence of similar equatorward meridional transport.


CRYSTAL-FACE all flights
020629F
020629T
020703
020511
020514
020516
020707
020709
020711
020713
020716
020719
020721
020723
020726
020728
020729
theta (K)
440
420
400
380
360
340
20
40
60
80
100
120
140
160
co (ppbv)


simulated carbon monoxide profiles for CRYSTAL-FACE
20020703
utt
20N
35N
40N
53N
58N
.5 20N
.5 35N
.5 40N
.5 53N
.5 58N
lin 20N
lin 35N
lin 40N
lin 53N
lin 58N
theta (K)
440
420
400
380
360
340
10
20
30
40
50
60
70
80
90
100
co (ppbv)


CRYSTAL-FACE all flights
o3<100
100<o3<150
150<o3<200
200<o3<300
300<o3>400
400<o3<500
500<o3<600
theta (K)
440
420
400
380
360
340
367
368
369
370
371
372
373
374
375
376
377
co2 (ppmv)


CRYSTAL-FACE all flights
o3<100
100<o3<150
150<o3<200
200<o3<300
300<o3>400
400<o3<500
500<o3<600
theta (K)
water vapor (ppmv)
340
360
380
400
420
440
0
5
10
15
20
25
30
35
40
45
50


CRYSTAL-FACE all flights
o3<100
100<o3<150
150<o3<200
200<o3<300
300<o3>400
400<o3<500
500<o3<600
theta (K)
440
420
400
380
360
340
0
50
100
150
co (ppbv)